UNIT – 8
THINKING AND PROBLEM SOLVING

Syllabus Mains:-

Piaget's theory of cognitive development; Concept formation processes; Information processing, Reasoning and problem solving, Facilitating and hindering factors in problem solving, Methods of problem solving: Creative thinking and fostering creativity; Factors influencing decision making and judgment; Recent trends.

Cognitive Development – Piaget's Theory

Jean Piaget (1896 - 1980) was employed at the Binet Institute in the 1920s, where his job was to develop French versions of questions on English intelligence tests.

He became intrigued with the reasons children gave for their wrong answers on the questions that required logical thinking. He believed that these incorrect answers revealed important differences between the thinking of adults and children.

Piaget (1936) was the first psychologist to make a systematic study of cognitive development. His contributions include a theory of cognitive child development, detailed observational studies of cognition in children, and a series of simple but ingenious tests to reveal different cognitive abilities.

Before Piaget's work, the common assumption in psychology was that children are merely less competent thinkers than adults. Piaget showed that young children think in strikingly different ways compared to adults.

According to Piaget, children are born with a very basic mental structure (genetically inherited and evolved) on which all subsequent learning and knowledge is based. The goal of the theory is to explain the mechanisms and processes by which the infant, and then the child, develops into an individual who can reason and think using hypotheses.

To Piaget, cognitive development was a progressive reorganization of mental processes as a result of biological maturation and environmental experience. Children construct an understanding of the world around them, then experience discrepancies between what they already know and what they discover in their environment.

According to Piaget, the mechanism underlying cognitive development is adaptation- the process of building mental representations, or schema, of the world though direct interaction with it. Adaptation, in turn, consists of two basic components. The first is assimilation, our tendency to fit new information into existing mental frameworks – to understand the world in terms of existing concepts, schemes and modes of thought. The second is accommodation our tendency to, later existing or mental framework in response to new information. Piaget suggests that it is the tension between these two components that fosters adaptation and cognitive development.

Jean Piaget viewed intellectual growth as a process of **adaptation** (adjustment) to the world. This happens through:

- Assimilation

– Which is using an existing schema to deal with a new object or situation.

- Accommodation

– This happens when the existing schema (knowledge) does not work, and needs to be changed to deal with a new object or situation.

- Equilibration

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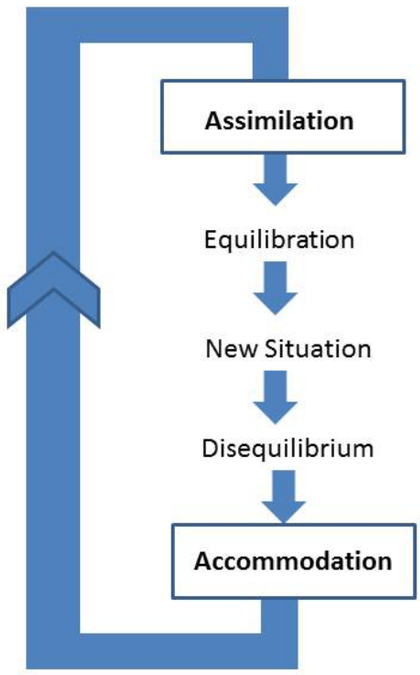

– This is the force which moves development along. Piaget believed that cognitive development did not progress at a steady rate, but rather in leaps and bounds.
Equilibrium occurs when a child's schemas can deal with most new information through assimilation. However, an unpleasant state of disequilibrium occurs when new information cannot be fitted into existing schemas (assimilation).
Equilibration is the force which drives the learning process as we do not like to be frustrated and will seek to restore balance by mastering the new challenge (accommodation).
Once the new information is acquired the process of assimilation with the new schema will continue until the next time we need to make an adjustment to it.

Piaget believed that newborn babies have a small number of innate schemas - even before they have had much opportunity to experience the world. These neonatal schemas are the cognitive structures underlying innate reflexes. These reflexes are genetically programmed into us.

For example babies have a sucking reflex, which is triggered by something touching the baby's lips. A baby will suck a nipple, a comforter (dummy), or a person's finger. Piaget therefore assumed that the baby has a 'sucking schema'.

Similarly the grasping reflex which is elicited when something touches the palm of a baby's hand, or the rooting reflex, in which a baby will turn its head towards something which touches its cheek, were assumed to result operations: for example shaking a rattle would be the combination of two schemas, grasping and shaking.

A child's cognitive development is about a child developing or constructing a mental model of the world.
Imagine what it would be like if you did not have a mental model of your world. It would mean that you would not be able to make so much use of information from your past experience, or to plan future actions.
Jean Piaget was interested both in how children learnt and in how they thought.
Piaget studied children from infancy to adolescence, and carried out many of his own investigations using his three children. He used the following research methods:
Naturalistic observation: Piaget made careful, detailed observations of children. These were mainly his own children and the children of friends. From these he wrote diary descriptions charting their development.
Clinical interviews and observations of older children who were able to understand questions and hold conversations.
Piaget believed that children think differently than adults and stated they go through 4 universal stages of cognitive development. Development is therefore biologically based and changes as the child matures. Cognition therefore develops in all children in the same sequence of stages.
Each child goes through the stages in the same order, and no stage can be missed out - although some individuals may never attain the later stages. There are individual differences in the rate at which children progress through stages.
Piaget did not claim that a particular stage was reached at a certain age - although descriptions of the stages often include an indication of the age at which the average child would reach each stage.
Piaget (1952) believed that these stages are universal - i.e. that the same sequence of development occurs in children all over the world, whatever their culture.

(1) The Sensorimotor Stage: It is a stage of learning to represent the world internally.

The first stage described by Piaget lasts from birth until somewhere between 18 and 24 months. During this period, known as the sensorimotor stage, infants gradually learn that there is a relationship between their actions and the external world. They discover that they can manipulate objects and procedure effect. In short, they acquire a basic grasp of the cause and effect.

Throughout the sensorimotor period, infants seem to know the world only through motor activities and sensory impressions. They have not yet learned to use symbols or images to represent objects / events. A 4 month old baby will not look for a toy that is hidden from view, however a nine month old will start searching for the object, because he has developed the idea of object permanence. Object Permanence is the understanding that object continue to exist even after they are hidden from view. Additional evidence that during the sensorimotor stage infants gradually acquire mental structures to represent the external world, is provided old, by the fact that by the time they are about 16 month old, they show deferred imitation – the ability to imitate actions performed by adults.

(2) The Per-Operational stage*:* This stage is marked by growth of symbolic activity. Sometime between 18 and 24 months, infants acquire the ability to form mental images or object and events. At the same time, languages develop to the point at which a young child begins to think in terms of verbal symbols. These developments mark the end of the sensormotor period and the start of the peroperational stage.

During the stage, which lasts until about the age of 7, children are capable of many actions they could not perform earlier. For example, they begin demonstrate make believe-play, in which they enact familiar activities, such as pretending to eat or go to sleep. In order to engage in make-believe-play, they must be able to represent these activities mentally and translate such representation into overt actions.

In this stage, the thought processes are limited by ego centrism. They have difficulty in understanding that other may perceive the world differently that they do. In Piaget's view, ego centrism lies behind another intriguing aspects of children's thought during the pre-operational period-something Piaget terms 'animistic thinking'. In such thinking, children attribute human feelings and motives to inanimate objects. Children in the preoperational stage also seem to lack understanding of relational terms such as darker, larger etc. 'Serialisation'-ability to arrange objects in order along a dimension and 'conservation' – knowledge that certain physical attributes of an object remain unchanged even though the outward appearance of the object is altered, are lacking at this stage.

(3) The stage of Concrete Operations: This stage is indicated by the emergence of logical thought.

According to Piaget, the mastery of 'conservation' marks the beginning of this stage and last till the age of 11. Children now, think more like adults and many important skills emerge. They also understand reversibility – the fact that many physical changes can be undone by reversing the original action. They also begin to make greater use of concepts in describing and thinking about the physical world. Children also begin to make use of cognitive maps, mental representations of spatial arrangements. Finally, children begin to engage in what Piaget terms 'Logical Thought'.

(4) The Stage of Formal Operations: Children at this stage deal with abstractions as well as reality.
At about 12 years of age, the final stage of cognitive development or formal operations is reached. Major features of adult thought make their appearance. While children in the stage on concrete operations can think logically, it appears that they can do so only about concrete events and objects. In contrast, those who have attained the stage of formal operations can think abstractly; they can deal not only with the real or concrete but with possibilities or relationships that do not exist but can be imagined.

Now, they also become capable of, what Piaget terms hypothetico-deductive thinking; that can formulate a general theory that includes all possible factors from this and they can reason deductively to formulate specific hypotheses that can be tested by examining the stage of formal operations demonstrate proportional reasoning. They can assess the logical validity of verbal

assertions, reason about the relationship between two or more propositions or assertions, rather than about only one at a time in isolation. Finally, individuals at this stage of development understand that words or statements can have several meanings, depending go the context.

While the thinking of children or adolescents closely approaches to that of adults, it still falls short of adult level, partly because of young people's relatively limited life experiences. Youngsters often use their new powers of reasoning to construct sweeping theories of religions, ethics or politics. While the reasoning may be logical, their theories are often naïve and incomplete. Piaget contends that, impressed with their personal theories, adolescents often fall prey to a new form of ego-centrism-called formal operational egocentrism. They cling rigidly to their views, refuse to believe that they might be incorrect, and assume that no other views can match theirs in terms of overall validity.

While individuals who have reached the stage of formal operations, there is no guarantee that they will engage in the aforesaid forms of thought. On the contrary, adults too slip back into less advanced modes of thought. They regularly confuse theories with evidence and they often make cognitive adjustments in existing evidence so that it fits with their theories, or adjust the theories to be more consistent with available evidence. In other words, having the capacity for logical does not assure that such systematic reasoning will actually occur.

Evaluation of Piaget's Theory

Support

- The influence of Piaget's ideas in developmental psychology has been enormous. He changed how people viewed the child's world and their methods of studying children. He was an inspiration to many who came after and took up his ideas. Piaget's ideas have generated a huge amount of research which has increased our understanding of cognitive development.
- His ideas have been of practical use in understanding and communicating with children, particularly in the field of education (re: Discovery Learning).

Criticisms

- Are the stages real? Vygotsky and Bruner would rather not talk about stages at all, preferring to see development as continuous. Others have queried the age ranges of the stages. Some studies have shown that progress to the formal operational stage is not guaranteed. For example, Keating (1979) reported that 40-60% of college students fail at formal operation tasks, and Dasen (1994) states that only one-third of adults ever reach the formal operational stage.
- Because Piaget concentrated on the universal stages of cognitive development and biological maturation, he failed to consider the effect that the social setting and culture may have on cognitive development (re: Vygotsky, 1978).
- Piaget's methods (observation and clinical interviews) are more open to biased interpretation than other methods. Because Piaget conducted the observations alone the data collected are based on his own subjective interpretation of events. It would have been more reliable if Piaget conducted the observations with another researcher and compared the results afterwards to check if they are similar.
- As several studies have shown Piaget underestimated the abilities of children because his tests were sometimes confusing or difficult to understand
- The concept of schema is incompatible with the theories of Bruner (1966) and Vygotsky (1978). Behaviourism would also refute Piaget's schema theory because is cannot be directly observed as it is an internal process. Therefore, they would claim it cannot be objectively measured.
- Piaget carried out his studies with a handful of participants (i.e. small sample size) – and in the early studies he generally used his own children (from Switzerland). This sample is biased, and accordingly the results of these studies cannot be generalized to children from different cultures.

The Nature of Thinking

There are a number of different aspects to the complex process of thinking. One of these involves organizing objects and events into specific mental categories known as concepts. For example, if someone plays a melody on a piano we may listen intently as the sound waves strike our ears. But we need a way to organize this information, to know how it is similar or different from other melodies we have heard. We do this by categorizing the melody as belonging to a certain class of music, or as representative of the work of a certain pianist, or perhaps by simply naming he tune we have just heard. This process is known as concept formation.

Concept formation is one important aspect of thought. Nine dots are arranged in a square. The task is to connect the dots by drawing only four straight lines without lifting your pencil from the paper. Can you solve this problem? To do so, you must come up with a new way of structuring your thoughts. Past experience is not terribly helpful. Many problems are like this task in that they require the problem solver to think creatively.

Concepts

A concept is a way of categorizing or classifying the people, objects, and events in the environment (Anglin). Consider, for example, the concept of dog. We know that certain things in the world belong to this concept, while others do not. However, this concept, like many others, is not acquired immediately. Rather, we gradually learn the identifying characteristics of a dog. We learn that a dog has for legs, a tail, a distinctive facial appearance, and that it makes a barking sound. These characteristics help us distinguish a dog from other animals, such as a cat (no barking sound) or a horse (longer legs, no barking sound). We also learn that there are different types of dogs, so that a Dalmatian is distinguished from an Irish setter or a golden retriever. Over an extended period of time, we make progressively more refinements in our concept of dog. Eventually, we know the examples or instances of this concept, that is, what should be included and excluded from the concept dog.

Of course, this example illustrates just one of the many kinds of concepts we possess. We form concepts for states (feeling young or being tired), for activities (working, playing), for mental abilities (knowing, learning), and even for difficult abstractions, such as beauty, truth, and justice. While these concepts are more complex, we acquire them in much the same fashion. Over a period of time, we learn the characteristics or features that are common to each concept.

Some of the concepts we form have clearly defined features that makes it relatively easy to determine whether something (such as a person or animal) “belongs” to the concept. For example, if we return to the concept dog, you will have little difficulty identifying as “instances” of this concept. You know that an Irish setter belongs, as does a German shepherd, and so forth. On a more abstract level, we can choose a concept such as bachelor. Here, too, you would have little difficulty knowing who belongs because the critical features, (adult, male, unmarried) are well defined. But suppose you were to consider the concept vehicle. We would all agree that an automobile is a good example of this concept. But if you were asked whether an elevator is a vehicle, you would probably respond “maybe” or “sort of.” This is because the exact boundaries of the concept vehicle are poorly defined. Concepts like vehicle are called “**fuzzy**” because it is sometimes difficult to make decisions about what belongs to the concept.

Acquiring Concepts

Concepts cannot really be taught. A parent, for example, could teach some of the defining features of certain concepts (such as Mommy or brother) but the child would have to learn other features through experience. More over, as Eleanor Rosch suggests, it is unlikely that we acquire concepts, especially “fuzzy” concepts, simply by discovering the critical defining features. Instead, we identify **prototypes**, which are the best examples of a concept. We use prototypes to determine whether less obvious stimuli belong to the concept. Many people, for instance, consider chair the best example of the concept furniture, and orange or apple the best example of the concept fruit (Rosch). These prototypes then serve as a useful reference point in deciding whether a particular example belongs with a particular concept. Thus, if you were considering

whether a telephone is an example of the concept furniture, you might compare a telephone with a chair because chair is prototypical example of furniture.

Research on "fuzzy" concepts has shown that people have a very strong intuitive sense about what is prototypical. If you examine the list of conceptsYou can easily tell the difference between the good and bad examples of each concept. In fact, this list represents the actual responses that subjects gave when asked to rank examples of furniture and other natural concepts.

Over the course of a lifetime, people develop a sense that some examples of fuzzy concepts are better or more prototypical than others. We expect apples to be red, even though they can be green, and we think that flying is prototypical of birds, even though some birds (like penguins) do not fly.

Most concepts are like this. They include members that have a number of different features. The prototypical example is helpful and instructive because it bears the strongest similarity to other members of the concept and the least similarity to members of different concepts.

Integrating Concepts

As useful as concepts are, we do not have the memory storage to keep track of an infinite array of ideas. We need to simplify our lives by integrating concepts. This permits us to learn and recall information more easily.

One way that we integrate concepts is to form **hierarchies**. The most abstract concept, animal, is at the top of the hierarchy, with the more specific concepts (bird, fish, and so on) shown below. Each concept has some associated features listed alongside it. This is an interesting model, but how can we tell if people actually organize concepts in this way?

uppose we design an experiment that requires people to infer the presence of properties not directly associated with a particular concept. For example, if we pose the question, "Does a bird eat?" and "Does a canary eat?" we are asking people to decide about a feature (eating) not directly associated with either bird or canary. If the hierarchical model is correct, it should take people longer to answer the question about the canary. To do so, they must move through two paths, canary to bird, bird to animal. When Allan Collins and M. Ross presented questions like these to adult subjects, they discovered that the hierarchical model accurately predicted response to questions that were further apart in the hierarchy.

Problem Solving

So far we have discussed the way we organize our thoughts into concepts. But we have not addressed the question of how thought helps us in problem-solving situations, ranging from relatively simple tasks, such as finding a route from one place to another, to difficult tasks that require detailed planning and a thorough consideration of alternatives. In this section, we will be concerned primarily with complex problems. These are problems that are not solved immediately but instead involve a series of stages that lead to an eventual solution.

Stage of Problem Solving

Although psychologists hold different notions about the stages involved in problem solving, we will concentrate on a proposal by **Allen Newell** and **Herbert Simon** that has application to a wide variety to problems. Newell and Simon proposed three distinct stages in problem solving. First, people try to divide the problem into smaller, manageable segments. Second, they look for a rule or hypothesis that will solve the particular segment they are considering. Finally, they evaluate their hypothesis. This three stages process is presented graphically in **fig.** where we note the presence of "feed back loops" that shows how the stages continue to cycle until the problem is solved.

(Figure)

The solution to this type of problem usually conforms to Newell and Simon's three-stage model. People often begin by considering the relationship among the six letters. By considering the relationship among just these letters, the problem becomes segmented and manageable. A second step is to search for a rule (a hypothesis) that explains why some letters go inside the circle and others outside. Finally, this hypothesis must be evaluated by determining whether it explains the placement of a subsequent group of letters inside or outside of the circle.

The solution to this problem is as you can see, letters with straight lines belong outside. If you began by analyzing the relationship between vowels and consonants, or by looking for a geometric pattern such as the first letter inside, the next three outside, and so forth, then you were forced to discard there hypotheses and begin again. Many problems require this type of recycling before a correct solution is achieved.

(Figure)

Strategies of Problem Solving----------

Some problems are solved **insightfully** when people suddenly restructure the way they perceive a situation. But other problems require a longer and more sequential solution. A game of chess is a good example of a more involved problem-solving situation. Each move is met by an opponent's counter move, which in turn requires a reanalysis of the situation. Typically, no sudden insight will determine the outcome of the game. Instead, the chess player must complete a series of moves that requires continuous planning and evaluation of the situation.

Problems like those of the chess game are open to a number of different options or strategies. One general strategy is to try to consider all possible solutions in order to pick the best one. However, this strategy may conflict with a different approach that calls for a more rapid and efficient solution. Problems solvers are sensitive to both demands. They want to ensure a correct solution, but they are also aware of the time and mental effort involved in investigating every possible solution. Let us look in detail at two major strategies problem solvers use, bearing in mind their conflicting demands

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Algorithms and Heuristics

Algorithms and heuristics are two major strategies available to problem solvers. They are also a common component of many computer programs. An **algorithm** is a step-by-step procedure in which the problem solver considers all possible solutions to a problem. An algorithms guarantees the discovery of an effective solution, but it may require an inordinate amount of time. Imagine using an algorithm to solve a crossword puzzle or to unscramble the following letters so as to make a word.

(Figure)

Solving the problem with an algorithm requires arranging the letters in all possible combinations. With an eight-letter word of eight different letters, this means 40,320 possible combinations? That is too many for a reasonable person to entertain.
What is needed to unscramble the letters is a heuristic, a short-cut that provides a reasonable chance for a correct solution. **Heuristics** are really rules of thumb or bits of knowledge that have

helped solve problems in the past. One that you might use with the scrambled letters is the relationship of consonant and vowels. You rarely find three consonants at the beginning of an English word, so you probably won't consider that possibility at the outset. In fact, research has shown that subjects initially focus on letter combinations that have a high probability of occurrence. A slightly different heuristic is to search for a partial solution involving only a few of the letters, then try to construct the longer world using all the letters. Although heuristics do not always work, they provide speedy solutions that can be quickly evaluated. The answer to this problem, incidentally, is SCRAMBLE, which points out another useful heuristics. Never underestimate the deviousness of people who construct scrambled-letter problems, better known as anagrams.

Sub-goals analysis

A somewhat different kind of problem-solving strategy, known as subgoal analysis, is commonly found both in the verbal descriptions of human problem solvers and in the operations of a computer program (Newell & Simon). Essentially, **subgoal analysis** is strategy of reducing a complex problem to a series of smaller problems, or subgoals. For example, the ultimate goal in chess is to put the opponent's king in checkmate, but as every chess-player knows, this is a long-range goal that must be preceded by a series of smaller moves. Similarly, when adult subjects confront the Tower of Hanoi problem shown in **fig**, they must search for meaningful sub-goals that will lead to the eventual solution. Take a moment to examine the **Tower of Hanoi** problem. All the rings on pet A must be moved to peg C, under two restricting conditions: (1) only the top ring on a peg can be moved, and (2) a ring cannot be placed on top of a smaller ring. What solution can you devise? Try the problem first, then consider the following analysis provided by Glass, Holyoak, and Santa.

(Figure)

The restricting conditions dictate that ring 3 must be placed on peg C first. This becomes a sub-goal in a successful to the problem, though it cannot be achieved immediately. Before ring 3 can be moved, rings 1 and 2 must be cleared away. Thus, a second sub-goal arises. Ring 1 must be moved first, but to which peg, B or C? Here the integration of sub-goals is important. If ring 1 is moved on peg B fist, then ring 2 must go to peg C. But if that occurs, then the first sub-goal (move ring 3 to peg C) will be impossible. However, if ring 1 goes to peg C, and ring 2 to B, then the following subsequent moves will be possible:

Ring 1 to peg B
Ring 3 to peg C
Ring 1 to peg A
Ring 2 to peg C
Ring 1 to peg C

Note that this approach to the problem involves a hierarchy of sub-goals, all of which must be carefully integrated (Glass et al.,). Failure to see the integration among sub-goals can produce a situation in which the problem solver feels "stumped." As you would expect, subjects find it increasingly difficult to integrate sub-goals in the Tower of Hanoi problem as the number of rings increases. -

Obstacles to Problem Solving

As you can well imagine, many factors influence problem solving. One of the most important is the individual's experiences, both immediate and past. Experiences guide our problem-solving abilities by establishing expected outcomes. Often without realizing it, we adopt subtle hunches-

what psychologists would call biases-as we attempt to solve difficult problems. But what served us well in one situation may well be our undoing in another.

1. Mental Set

When we establish a particular orientation to problem, and maintain it over time, we have adopted a mental set. Mental sets can be helpful, but not if they become too inflexible. However, some situations seem to induce protracted mental sets. As an example, consider the classic water-jar problem devised by Abraham Luchins.

In Luchins' experiment, the subjects were asked to determine how to measure a require amount of water with the three jars labeled A, B and C. For example, in Problem 1, the task is to measure exactly 100 units of water. Jar A measures 21 units; Jar B, 127; and Jar C, 3. Many subject puzzle over the problem momentarily but then discover a simple rule that will produce the required amount; jar B minus Jar A, minus twice Jar C. With the solution in hand, they proceed to the second problem and discover that once again the exact same rule works. The subjects then apply this rule to Problems 3 through 6 and discover that it continues to produce the correct answer. Now the subjects confront Problem 7 and 8, and suddenly they are stumped. The rule no longer works. Indeed many subjects cannot find a way to solver Problem 7 and 8. why? Because they have developed a **mental set**, a particular way of looking at the problem which may interfere with solving new and different problems. Successful past experience with a particular rule now becomes as obstacle to finding a new solution. Actually the solution to Problem 7 and 8, as you may have discovered, is simpler than the solution to the earlier problems. The rule, "Jar A minus Jar C," yields the correct answer.

(Figure)

2. Functional Fixedness

Perhaps the best-known example of the influence of mental set on problem solving is a phenomenon known as **functional fixedness**, an idea about the way objects should be used, based on past experience, that is relatively difficult to modify. This phenomenon was first described in a series of well-known experiments demonstrating that people develop strong or fixed notions about an object's functions because of past experience (Duncker; Maier). For example, hammers are used to drive nails, scissors are used for cutting, and so forth. Sometimes past experience with objects disposes us to overlook the fact that many different actions can be performed with the same object. For instance, consider the sting problem described in Maier's (1931) early work on functional fixedness. Two strings, hung from a ceiling, are positioned so that a subject cannot reach both of them at the same time. The room is otherwise empty except for a table with a pair of scissors lying on the top. The subject is asked to tie the two strings together while remaining in one place on the floor.

The solution to the problem is simple enough once the subject overcomes a strong tendency to think of the scissors simply as a cutting tool. By tying the scissors to one of the strings and then swinging the string with the scissors back and forth, the subject is able to grasp both strings at the same and tie them together.

---------- **Reasoning**

The ability to reason is obviously an important aspect of human thought. Though commonplace, reasoning is perhaps more complex than you imagine. To comprehend the process, we must understand not only how people reason, but what factors interfere with sound reasoning. We will examine both these issues in our discussion of two important aspects of reasoning: deductive and inductive reasoning.

1. Deductive Reasoning

We are called upon to reason in several different ways. In some circumstances, we must emulate the skills of the great detective Sherlock Holms and arrive at a conclusion after sifting through all the pertinent clues. When we do so, we engage in **deductive reasoning**, the ability to draw logical conclusion from available evidence.

In practice, deductive reasoning usually involves careful analysis of one or two key statements, followed by a conclusion that is drawn logically from the information presented in the statements. For example, consider what conclusions you would draw from the following statement:

If you get an A on the final exam, you will get an A in the course.

One conclusion is obvious. An A on the final exam overrides any other grades received during the semester and guarantees an A in the course. But this conclusion is so compelling that it forces some people to form a second conclusion that does not follow logically, namely, that you must obtain an A on the final to receive an A in the course.

This is just one example of the pitfalls in deductive reasoning. All of us tend to have biases-particular ways of looking at a problem-that influences our ability to draw logical inferences. These biases are not always apparent, but on occasion we confront problems that are so counterintuitive they actually lead us toward logical errors. Perhaps the best example is found in one type of deductive reasoning problem, the syllogism.

A syllogism is an argument consisting of two statements assumed to be true (called premises), and a conclusion that follows logically from the premise. The task is to decide whether the conclusion is valid or invalid, or whether a conclusion is even possible. The argument below provides a classic example of a syllogism:

All men are mortal
Socrates is a man.
Therefore, Socrates is mortal.

This is an example of a straightforward and relatively easy syllogism. Most people do quite well when confronted with syllogisms like these. However, our ability to reason deductively is quite fragile. Often the form or structure of the syllogism influence people's judgments. Consider the following example:

All As are Bs.
All Cs are Bs.
Therefore, all As are Cs.

Logically, this is quite similar to the first syllogism. However, people find this problem much more difficult. Dealing with more abstract terms in the premise is one reason why. We are not used to symbols (As, Bs) as substitutes for words. Consider the same problem stated differently.

All Chevrolets are automobiles.
All Novas are Chevrolets.
Therefore, all Chevrolets are Novas.

It is now apparent that the conclusion is invalid. However, note that in its more abstract form, the conclusion seems to follow naturally from the premise. We are drawn more easily toward a logical error.
Clearly, deductive reasoning is a complex process. Subtle aspects of the structure of an argument can lead people toward faulty conclusions. However, these errors are not random mistakes. On the contrary, they reveal interesting dimensions of our deductive skills.

2. Inductive Reasoning

On some occasions, we must reason by taking a few observations and working our way "upward" toward a general conclusion. This is what a doctor does when you arrive at the office

with some vague symptoms. This type of reasoning is known as **inductive reasoning** because it involves the discovery of a general rules or principle that is derived from specific observations.

Inductive reasoning is really one form of hypothesis testing. We begin with one or more observations and try to reach a general conclusion. Take the familiar example of a car that won't start. Is the battery dead? Are the spark plugs worn out? Is the starting motor disabled? The skilled mechanics listens to the car, makes some observations with appropriate tools, and reaches a conclusions.
Psychologists typically study inductive reasoning by creating small problems that can be solved in the laboratory or classroom setting. Two familiar examples are series completion problem and analogies. In a series completion problem, you are asked to examine an incomplete series and determine what elements come next. A number series is often used; 3, 7, 15, 31,---,----,---,

Analogies require subjects to induce a relationship among known elements. A verbal analogy is typical:

Apple; Oranges as
Hammer: chisel, tool, stick, hat

You may have encountered both of these types of problems on aptitude or intelligence tests. Analogies, in particular, are often found on exams used for admission to college and graduate schools, suggesting that society places considerable value on this kind of inductive reasoning.

----------Decision Making

Perhaps the most practical aspect of thought is the ability to make decisions. Decision making is something we do on a daily basis, but most decisions are relatively minor, such as what we will eat or what movie we will see. However, on occasion we face major decisions, such as which college to attend or what career to begin. These decisions may well have a lasting impact.

We want to consider two basic aspects of decision making: (1) the factors that influence the choice people make, and (2) the factors that bias or interfere with decision making.

1. Choices in Decision Making

A decision involves a choice, and as such it presents people with a potential conflict. Should a couple, for example, have a child and derive the pleasure that comes from parenting, or would they prefer the greater freedom they have without children? Should you begin writing your term paper this weekend, or should you visit a friend and postpone writing for a few days?
Psychologists find that two factors influence the outcomes of these and other decisions. One is the utility, or value, that people assign to the choices involved in the decision. If you feel that a weekend away from school work is an absolute necessity, you are likely to choose that over beginning your term paper. Time away has greater utility to you. However, you will also calculate the probability that each choice will be fully realized. The probability issues becomes a question of how likely it is that the weekend will be enjoyable versus how likely it is that you can complete the term paper at some other time. Both utility and probability influence the decision-making process.

2. Heuristics in Decision Making

Decision involve judgments. People must decide how likely it is that some particular outcome will occur. To do this, they often rely on implicit rules. We noted earlier that useful rules of thumb are known as heuristics. But how do heuristics serve the decision-making process? Consider the following description of an individual named Steve:

Steve is very shy and withdrawn, invariably helpful, but with little interest in people, or in the world of reality. A meek and tidy soul, he has a need for order and structure, and a passion for detail.

Subjects were presented with this description and then asked to decide how likely it was that Steve was involved in one of a number of different occupations, for example, musician, salesman, physician, pilot, or librarian. The experimenters, Amos Tversky and Daniel Kahneman, were interested in what factors the subjects considered in making a judgment about Steve's occupation. Most people considered only one factor – the personality characteristics given in the description. Because Steve was described as shy, introverted, and withdrawn, subjects frequently gusseted that he was a librarian and rarely suggested that he was a salesman. In doing so, the subjects were relying on the representativeness heuristic. They held certain stereotypes about the typical or representative member of each of the occupations, and they matched these to the information available on Steve. Notice that in using only this heuristic they ignored other factors that might have helped predict Steve's occupation. For example, the subjects might have inquired about the percentage of people in the population at large who are involved in each of the occupations.

Heuristics are useful in the decision – making process because they provide people with a ready answer, but they can also be misleading. People not only fail to inquire about a potential source of information, as in the case of Steve, but sometime actually ignore information that has been supplied. In one demonstration of this point, two group of subjects were told to examine the personality profile of one individual and then decide whether the individual was a lawyer or an engineer. All subjects believed that the profile was randomly selected from a group was told that the proportion of lawyers to engineers was just the opposite; that is, 30 lawyers to 70 engineers. The task was to decide the occupation of the one person whose profile was selected. Logically, we would expect subjects to use the known proportions to make their judgments more accurately. In fact, both groups ignored the proportions and based their judgments solely on the match between the profile characteristics and stereotypes of lawyers and engineers. As a result, the two groups came to virtually the same conclusions about the occupation of the individual they were considering.

---------- CREATIVE THINKING

Creativity: Generating the Extraordinary

Suppose you were asked to name people high in creativity: Who would be on your list? When faced with this question, many people name such famous figures as Albert Einstein, Leonardo da Vinci, Thomas Edison, Sigmund Freud. What do these individuals have in common? All were responsible for producing something-a theory, inventions-viewed by other people as unexpected and new. More formally, psychologists generally define **creativity** as involving the ability to produce work that is both novel (original, unexpected) and appropriate (it works-it is useful or meets task constraints). Probably not, because while it is certainly originally, it really isn't practical! The United States Patent Office-and patent offices in other countries, too-apply the same criteria to patent applications: Not only must an idea be new, but it must be practical too.
Clearly, creativity is important; after all, it provides us with new knowledge and new inventions that can improve the quality of human life. It is somewhat surprising to learn, therefore, that until recently it was not the subject of extensive study by psychologists. Why was this so? One important reason was that although several methods for measuring creativity existed-for instance, asking individuals to come up with as many uses for everyday objects as possible, or to formulate as many ways of improving a product as possible none of these seemed to be completely satisfactory. They did not seem to capture all aspects of creativity: as it occurs in real-life situations. Another problem was the fact that the concept of creativity was associated, in many people's minds, with forces outside the realm of science-for instance, with vague notions of "the creative spirit". This made psychologists somewhat reluctant to study this topic.

During the past two decades, however, this situation has changed and rapid advances have been made in our understanding of creativity. Because creativity is clearly related to certain aspects of intelligence, and because it is an important topic in its own right, I'll now describe what psychologists have discovered about this fascinating topic.

Contrasting Views of Creativity

A basic question about creativity is "What factors produce it?" Several contrasting answers have been proposed. Cognitive psychologists, for example, have tended to focus on the basic processes that underlie creative thought. Research findings indicate that such processes as retrieval of information from memory, association, synthesis, transformation, and categorical reduction (mentally assigning objects to basic categories) may all play a role in creativity. Moreover, a cognitive approach to creativity calls attention to the fact that creativity is part of our everyday lives: Each time we utter a new sentence or understand a new concept we are showing creativity. Thus, a key task in the study of creativity is that of distinguishing between this kind of everyday creativity (termed mundane creativity) and exceptional creativity-the emergence of something dramatically new, such as the idea of integrated circuits, which made modern computers possible.

What differentiates these two kinds of creativity? According to Perkings, one psychologists who has focused on this issue, the difference may lie in the fact that everyday creativity occurs with respect to problems for which our past knowledge and experience give us valuable clues: We know where to look for a solution. In contrast, exceptional creativity may arise in what he describes as Klondike spaces-in areas where, like the miners of long ago who searched for gold in the Klondike, we don't know even where to begin looking. When we do find a solution in such situations, it is likely to be dramatic and to require thinking that is "outside the box"-thinking that breaks out of what I often describe as "mental ruts."

The cognitive approach to creativity has been dominant in psychology, but other approaches exist as well. For instance, social psychologists have often focused on the personality traits that make people creative and the environmental conditions that either encourage or discourage creativity. And still other researchers have focused on the motivation behind exceptional

creativity-the kind of intrinsic motivation, which can be sustained from within in the absence of external rewards.

While all of these approaches have certainly added to our understanding of creativity, a view known as **confluence approach** has gained considerable acceptance. This view suggests that in order for creativity to occur, multiple components must converge. For example, according to Lubart, creativity requires a confluence of six distinct resources:

- Intellectual abilities: The ability to see problems in new ways, the ability to recognize which of one's ideas are worth pursuing, and persuasive skills-the ability to convince others of these new ideas.
- Knowledge:-Enough knowledge about a field to move it forward.
- Certain styles of thinking: A preference for thinking in novel ways and an ability to see the big picture-to think globally as well as locally.
- Personality attributes: Such traits as willingness to take risks and to tolerate ambiguity. Intrinsic, task-focused motivation: Creative people usually love what they are doing and find intrinsic rewards in their work.
- An environment that is supportive of creative ideas.

Only when all of these conditions are present, Lubart and other argue, can a high level of creativity emerge.

Research on Creativity: Evidence for the Confluence Approach

A growing body of evidence offers support for the confluence approach. For example, consider one creative (!) study by Lubart and Sternberg. In this study, forty-eight adults ranging in age from eighteen to sixty-five were asked to produce creative products in each of four domains: writing, art, advertisings showing "hope" and "rage" and "the earth from an insect's point of view." With respect to advertising, they were asked to design television ads for bow ties and the Internal Revenue Service. All the products participants created were rated for overall creativity, novelty, and perceived effort. Participants also completed a measure of fluid intelligence, a measure of thinking style, and two personality measures.

Results indicated, first, that there was considerable agreement among raters: they agreed on what was creative and what was not creative. This is an important finding, because it indicates that creativity can be studied scientifically. Second, it was found that creativity in one domain (art, writing, and so on) was only moderately related to creativity in other domains. Thus, as common sense suggests, people can be creative in one area but not in another. Third, intellectual ability, thinking style, and personality were all significantly related to creativity.

Taken together, these findings, and those of other recent studies, offer support for the confluence approach. Creativity, it appears, requires the convergence of many factors for its emergence. None of these factors are unusual in and of themselves, but together they produce outcomes and results that are, in some cases, extraordinary.

Creativity Tests (Torrance & Rat)

Tests of Creativity

Tests of creativity measure divergent thinking. Divergent thinking refers to that aspect of the mental process where the individual expands to many correct solution of problems on the basis of a small amount of information. In this way, divergent thinking is different from convergent thinking where one seeks to synchronise or reduce several information's to one correct answer. Convergent thinking is mostly measured by the general mental ability test or the intelligence test. Consistent with the above view, tests of creativity require the examinee to give the correct and appropriate response to the given situations. The following are the brief discussion of the two important tests of creativity.

The Torrance tests of creativity was developed by Torrance. This test consists of two sections – verbal and figural. The verbal section includes (1) ask and guess, (2) product improvement, and (3) unusual uses. In the ask and guess subsection, the examinee is given a picture and asked to describe what had led to the scenes in the picture and what might happen net in the product improvement subsection, a picture of toy is given to the examinee who is encouraged to suggest changes in the toy so as to make it more fun for playing, and in the unusual cases subsection the examinee is asked to give as many unusual uses as he or she can of a common object. The figural section requires the examinee to draw a picture representing an object and to tell an interesting and exciting story with a picture. Each subject of the figural section gives something to the examinee to start with. For example, he may be given a circle with the instruction to construct as many figures as possible, with the circle as the key part in each figure. The Torrance test can be used with both small children and adolescents. The test is administered individually and orally for children below the fourth grade. On the basis of this test, three scores are given to each examinee: fluency (which indicates total number of acceptable responses); flexibility (which indicates the number of categories in the manual used by the examinee), and originality (which indicates the number of responses not found in the list of frequent responses). No norms are available and therefore, each examinee's total score is evaluated against a set of common criteria for creative achievement.

The Remote Associates Test (RAT) is another test for creativity, which has been developed by Mednick and Mednick in 1971. the test is meant for high school students and consists of 40 items. The items of the test are such that the examinee is presented with three words and asked to give the fourth word, which may be related to each of the three words. Those three words are thought to indicate remote associative clusters and the fourth word a mediating link. One minute time is allowed in each item and thus, the entire test takes about 40 minutes. The serious criticism of the RAT is that its validity is not established. Due to the lack of validity Worthen and Clark (1971) contended that the RAT was a better measure of sensitivity to the structure of language rather than a
measure of creative achievement.

MORE ABOUT PROBLEM SOLVING AND CREATIVITY

UNDERSTANDING THE PROBLEM

PAYING ATTENTION TO IMPORTANT INFORMATION
METHODS OF REPRESENTING THE PROBLEM

PROBLEM-SOLVING APPROACHES

THE MEANS-ENDS HEURISTIC
IN DEPTH: THE ANALOGY APPROACH

FACTORS THAT INFLUENCE PROBLEM SOLVING

EXPERTISE
MENTAL SET
FUNCTIONAL FIXEDNESS
WELL-DEFINED AND ILL-DEFINED PROBLEMS
INSIGHT AND NON-INSIGHT PROBLEMS

CREATIVITY

DEFINITIONS
MEASURING CREATIVITY

Problem solving is inescapable in everyday life. In fact, most jobs require some kind of problem solving – whether we consider managers, auto mechanics, doctors, teachers, counselors, or some other occupation.
You use problem solving when you want to reach a certain goal, but that goal is not readily available. You face a problem whenever a gap exists between where you are now and where you want to be – and you do not know how to cross that gap.

A problem consists of three features: (1) the original state, (2) the goal state, and (3) the rules. For example, suppose you want to go shopping in a nearby town. The **original state** describes the situation at the beginning of the problem. In this case, it might be, "I am in my room, five miles from that town, with no car and no public transportation." The **goal state** is reached when the problem is solved. Here, it would be, "I want to be in a town five miles away." The **rules** describes the restrictions that must be followed in proceding from the original state to the goal state. The rules in this hypothetical problem might include the following: "I can't borrow a car from a stranger" and "I can't drive a stick-shift car." Think about a problem you have recently solved and determine the original state, goal state, and rules, so that you are familiar with these items.

One aspect of problem solving that has received relatively little attention is **problem finding.** One example of problem finding was reported by leaders of a British company, who discovered that they were requesting unnecessary paperwork from their employees. The company leaders had previously been unaware that any problem existed. One year after finding the problem, 26 million cards and sheets of paper were eliminated – and presumably employees felt less overwhelmed. However, the solution would never have occurred if the problem hadn't first been discovered.
Children seem to seek out problems spontaneously, though adults typically do not. Some educators argue that our formal education discourages us from learning to find problem and ask questions.

1. Understanding the Problem

Some years ago, the companies in New York City skyscraper faced a major problem. The people in the building were continually complaining that the elevators moved too slowly. Numerous consultants were brought in, but the complaints only increased. When people threatened to move out, plans were drawn up to add an extremely expensive new set of elevators. Before reconstruction began, however, someone decided to add mirrors in the lobbies near the elevators. The complaints stopped. Apparently, the original problem-solvers had not properly understood the problem. In fact, the real problem wasn't the speed of the elevators, but the boredom of waiting for them to arrive.

What do we mean when we say that we understand a problem? According to **Greeno**, **understanding** involves constructing an internal representation. For example, if you understand a sentence, you create some internal representation or pattern in your head so that concepts are related to each other in the same way that they are related to each other in the original sentence. To create this pattern in your head you must use background knowledge, such as the meaning of the various words in the sentence.
Greeno believes that understanding has three requirements: coherence, correspondence, and relationship to background knowledge.

A coherent representation is a pattern that is connected, so that all the parts make sense. For example, consider Greeno's sentence, "Tree trunks are straws for thirsty leaves and branches". That sentence remains at the level of complete nonsense unless you see that it is based on the similarity of tree trunks and straws in moving liquid. Once you see the analogy, the fragments of the sentence become united..

Greeno also propose that understanding requires a close correspondence between the internal representation and the material that is being understood. Sometimes the internal representation is incomplete, and sometimes it is inaccurate. Important relations among the parts may be left our or mismatched. Think about an occasion when you noticed that an internal representation and the material to be understood did not correspond. I recall my mother giving her friend a recipe for yogurt, which included the sentence, "Then you put the yogurt in a warm blanket." The friend looked quite pained and asked, "But isn't it awfully messy to wash the blanket out?" The friend's internal representation unfortunately omitted the fact that the yogurt was in a container.

Greeno's third criterion for good understanding is that the material to be understood must be related to the understander's background knowledge. This point has probably occurred to you if you have ever found yourself enrolled in an advanced level course without the proper prerequisite courses or if you have ever looked at a professional article in an area unfamiliar to you. Vocabulary and concepts must be familiar for material to be understood. Greeno summarizes his previous research on this topic, which involved people solving probability problems. Those who were told the meanings of basic concepts in probability were better at solving word problems than those who were only taught the formulas.
The first step in understanding a problem is deciding what information is crucial and which is irrelevant. The second step is deciding how to represent the problem.

Paying Attention to Important Information

To understand a problem, you must pay attention to the crucial information, ignoring irrelevant information. Notice, then that one complex cognitive task – problem solving – relies on another cognitive activity – **attention**.

Simon and Hayes asked 20 people to solve a problem, thinking aloud as they worked. The authors recorded what the participants said and also recorded the number of times each sentence was reread before the participants made their first move. Sentence 3 was reread a total of 23 times; this sentence describes the present situation. Sentence 4 was reread only nine times; this sentence describes the goal state. Sentence 5 was reread 32 times; this sentence describes the rules. All other sentences combined were reread only five times.

What kinds of sentences did people pay attention to? Simon and Hayes argue that they will reread a sentence if (1) they believe the information in the sentence is relevant to the task and (2) they have not stored the information in memory. For instance, Sentences 1 and 2 contain information that is either irrelevant (for example, that the monsters each have five hands) or repeated later (for example, the sizes of the monsters and the globes). The last part of Sentences 4 is relevant to the task, but the information in that sentence – that each monster must hold a globe of a corresponding size – can easily be stored in memory. Consequently it does not deserve rereading.

Sentences 3 and 5, in contrast, are both relevant and complicated. These are the sentences that are difficult to store in memory. As a result, people must return to these sentences and reread them before they begin the problem. Furthermore, Simon and Hayes noticed that people also reread these sentences after they had begun to make moves. They seldom reread the other sentences once they had begun the problem.

. Kintsch and Greeno have designed a program that solves arithmetic word problems, such as "Joe has eight marbles. He has five more marbles than Tom. How many marbles does Tom have?" Obviously, the arithmetic operation in this question is no challenge to a computer. However, humans can easily pay attention to some words and ignore others. A major challenge is designing a computer program is specifying how the system determines which words deserve attention.
Attention is also important in problem understanding because competing thoughts can produce divided attention. **Bransford** and Stein presented algebra word problems to a group of college students. You remember these problems – a typical one might ask about a train traveling in one direction and a bird flying in another direction. The students were asked to note their thoughts and feelings as they inspected the problem. For a substantial number of students, their initial

reactions to the problem included thoughts, such as “Oh no, this is a mathematical word problem – I hate those things” and “Boy, am I going to look stupid!” These negative thoughts occurred frequently throughout the 5 minutes allotted to the task. Clearly, they drained attention from the central task of problem solving. Real – world problem solving frequently occurs in divided-attention tasks. Hunt and **Lansman** point out, for example, that the task of driving a car through an unfamiliar city in rush-hour traffic is a divided – attention issue. You must solve the problem of reaching your goal while watching other cars, pedestrians, and traffic lights.

Consider too, the number of problem we face in everyday life in which the major challenge is discovering what information is important and what is irrelevant. Your statistics professor, for example, may include a problem on a test that has many details about the experimental design that are really not important for the solution of the problem. There may even be extra statistical information that you will not need in finding the answer. The challenge in the problem may really be to decide what information merits attention. Also, consider how this idea of discovering essential information can be applied to some riddles. Halpern poses this one:

Suppose you are a bus driver. On the first stop you pick up 6 men and 2 women. At the second stop 2 men leave and 1 woman boards the bus. At the third stop 1 man leaves and 2 women enter the bus. At the fourth stop 3 men get on and 3 women get off. At the fifth stop, 2 men get off, 3 men get on, 1 woman gets off and 2 women get on. What is the bus driver’s name?

A major problem in understanding a problem is focusing on the appropriate part of the problem. If you paid attention to the bus driver problem, you could solve it without rereading it. However, if you didn’t pay attention, you can locate the answer in the first sentence.

Methods of Representing the Problem

As soon as the problem solver has decided which information is essential and which can be disregarded, the next step is to find a good way to represent the problem. **Simon** and Hayes argue
If people regard problem as being abstract, then a difficulty arises. After all, an abstract problem is difficult to keep in memory while you perform operations. Therefore, people typically invent some method of representing the abstract problem is a concrete way – a particular concrete way that shows only the essential information.

i. Symbols. Sometimes the most effective way to represent an abstract problem is by using symbols, as students learn to do in high-school algebra. The usual way of solving this problem is to let a symbol such as *m* represent Mary’s age and a symbol such as *s* represent Susan’s age. We can then “translate” each sentence into a formula. [an algebra problem,$m = 2s - 10$]

Of course, as you learned in algebra, the major problem is learning to translate words into symbols. Schoenfield describes how calculus students were asked to rephrase simple algebra problem statements so that they were more understandable. About 10 percent of the rephrasings included information that directly contradicted the input, and 20 percent contained information that was so confused that it was unintelligible. If you misunderstand a problem, you will not translate it accurately into symbols. (And, incidentally, a proper understanding of a problem does not guarantee an appropriate translation into symbols!)

It seems likely that many errors occur in translating words into symbols, because people either have difficulty with the linguistic interpretation of the words or because they fail to remember all the critical material. In previous chapters, we have seen that people remember material that is consistent with their prior schemas. This same schema-consistent processing occurs when people try to solve problems.

One common problem in translating sentences into symbols is that the problem solver often simplifies the sentence, thereby misrepresenting the information. **Mayer** asked college students

to read a series of eight algebra story problems, and then recall them later. The problems contained some relational propositions such as “the rate in still water is 12 miles per hour more than the rate of the current” and simpler propositions such as “the cost of the candy is $1.70 per pound.” The participants recalled only 71 percent of the relational propositions correctly, in contrast to 91 percent of the simpler propositions. Further analysis showed that the errors on the relational propositions frequently involved changing those statements into simpler forms, such as “the rate in still water is 12 miles per hour.”
A further problem arises in the translation process because bring their previous misconceptions with them when they begin to solve a problem. For example, several researchers have asked students without any background in physics to solve physics problems. Many of them hold misconceptions about the way objects move. Unfortunately, these misconceptions interfere with the proper translation of words into symbols.

Lists. In many problems, however, translating words into symbols will not get us very far. For example, the monster problem cannot be handled by the symbols used in an algebra problem. We could approach the problem by making a list,

Matrices. Simon and Hayes found that more than 50 percent of participants spontaneously constructed some kind of matrix to represent the monster problem. A matrix is a chart that shows the possible combinations. A matrix is an excellent way to keep track of objects, particularly when the problem is a complex one and the relevant information is categorical.

Hierarchical Tree Diagram. a problem can be represented in several different ways. A more satisfactory alternative for representing the problem is a hierarchical tree diagram, a figure that uses a treelike structure to specify every possible outcome and is especially effective in assessing the mathematical probability of various outcomes.. Keren found that 80 percent of students who used a hierarchical tree diagram eventually produced the correct answer. In other words, the hierarchical tree diagram was twice as successful as the simple list in producing the correct response.

Graphs. For some problems, however, symbols, lists, matrices, and hierarchical tree diagram are not useful. Consider, for example, the Buddhist monk problem

Visual Images. Other people prefer to solve the Buddhist monk problem visually. One young woman who chose a visual approach to this problem reported the following:

I tried this and that, until I got fed up with the whole thing, but the image of that monk is his saffron robe walking up the hill kept persisting in my mind. Then a moment came when, superimposed on this image, I saw another, more transparent one, of the monk walking down the hill, and I realized in a flash that the two figures must meet at some point some time-regardless at what speed they walk and how often each of them stops. The in reasoned out what I already know: whether the monk descends two days or three days later comes to the same; so I was quite justified in letting him descent on the same day, in duplicate so to speak.

As Koestler points out, a visual image has the advantage of being irrational. After all, how could the monk meet himself coming down the mountain? Thus, the visual image can let us escape from the boundaries of traditional representations. At the same time, however, the visual image is somewhat concrete; it serves as a symbol for a theory that has not yet been thoroughly developed. This may partially explain why visual representations are particularly useful in solving novel problems.
We need to point out that problem-solvers do not exclusively use just verbal representations or just imagery to solve a puzzle. For example, the image of the monks is certainly associated with some words. Also, some imagery representations may be more effective than others. For example, Adeyemo asked college students to construct a novel coat rack, given only a specified set of equipment. Students who created as image of an imaginary structure were much more successful in solving the problem than were students who created an image of a familiar coat rack.

Which Method is Best? We have seen that problems can be represented by symbols, lists, matrices, hierarchical tree diagrams, graphs, and visual images.

Which method works best for this particular problem? Schwartz examined this question in an article, "Modes of Representation and Problem Solving: Well Evolved is Half Solved." Schwartz found that the representation method was related to whether the participants solved the problem. When people used a matrix of represent this kind of problem, 74 percent reached the solution. Other representations produced a solution between 40 percent and 55 percent of the time. People who did not use any particular representation method were successfully only 25 percent of the time. For this kind of problem, the matrix representation was clearly the most effective.

We should point out, however, that Schwartz's study shows only that the representation method is related to the frequency of solution. We may be tempted to conclude that this method caused a higher frequency of solution, so that problem solvers could improve their accuracy by shifting to matrix representation. However, another interpretation for the data is that people who choose matrix representations are good problem solvers, and people who choose other representations are poor problem solvers. Telling these other people about matrix representation may not aid them substantially. At present, however, we can conclude that people who spontaneously use matrix representation are effective in solving this kind of problem.

Problem Solving Approaches----------

Once you have represented the problem, you can use many different strategies to attack it. Some strategies are very time consuming. An **algorithm** is a method that will always produce a solution to the problem, sooner or later. One example of an algorithm is the method called **systematic random search**, in which you try out all possible answers using a specified system. With such an inefficient algorithm, however, the exam would probably be over by the time the solution was obtained.

Newell and **Simon** observe that the time taken to search for an answer to a problem is roughly proportional to the total size of the problem space. The **problem space** is all the possible solutions to the problem that have occurred to the problem solver. Thus, the problem may have other solutions, but if the problem solver is not aware of these solutions, they are not included in the problem space.
Notice how the problem space can vary. The problem space for the anagram YBO is very small, whereas the problem space for the anagram LSSTNEUIAMYOUL is enormous.

Algorithms are often inefficient and unsophisticated. Other, more sophisticated methods cut down the part of the space that must be explored to find a solution. The problem solver thus begins with a large space at first. However, she or he applies relevant information about the problem in order to reduce the size of the problem space, leaving a relatively small space to examine. For example, to solve that lengthy anagram, you might pick out initial combinations of letters that are pronounceable, thereby narrowing the problem space. Perhaps you would reject combinations such as LS, LT and LN, but consider LE, LU, and hopefully SI. This strategy would probably, lead you to a solution much faster than a systematic random search of all the more than 87 billion possible arrangements of the 14 letters in SIMULTANEOUSLY.

The strategy of looking only for pronounceable letter combinations is an example of a heuristic. As you know from other chapters, a heuristic is a rule of thumb. In problem solving, a **heuristic** is a rule of thumb involving a selective search, looking at only the portions of the problem space that are most likely to produce a solution.

We noted that algorithms such as a systematic random search will always produce a solution, although you may age a few years in the process. Heuristics, in contrast, do not guarantee a solution. For example, suppose you were given the anagram IPMHYLOD. If you used a heuristic of rejecting unlikely initial combinations such as LY, you would fail to find the correct solution,

LYMPHOID. When making a decision, you'll need to weigh the benefits of an algorithm's speed against the costs of possibly missing the correct solution.
Psychologists have conducted more research on problem solvers' heuristics than on their algorithms. One reason is that algorithms do not exist for most everyday problems (for example, how to get to a nearby town). Furthermore, people are more likely to use heuristics. Two of the most widely used heuristics are means-ends analysis and analogy.

a.The Means-Ends Heuristic

When you use the means-ends heuristic, you divide the problem into a number of **subproblems**, or smaller problems. You then solve each subproblem by detecting the difference between the original state and the goal state and then reducing the difference between these two states. The name **means-ends analysis** is appropriate, because it involves figuring out the "ends" you want and then figuring out the "means" you will use to reach those ends. As Sweller and Levine note, means-ends analysis concentrates the problem solvers' attention on the difference between the current problem state and the goal state.

Every day we all solve problems by using means-ends analysis. Suppose, for example, that you are in the library at 9:37 in the morning and have just realized that you must miss an 11:00 class in industrial psychology because you must register for next semester's courses during the period. You know that the lecture will be important, and there will be an examination during the next class session that includes material from the class you must miss. Because of the exam, you realize that no one will lend you the notes enough to copy them – not even your good friend Susan, who takes meticulous notes and would ordinarily be most cooperative. The original state, unfortunately, has you in the registration line at 11:00 while Susan takes notes that you may never see. The goal state would have you holding a copy of those fine notes. The problem has three subproblems: (1) discover a way for Susan to take notes for you, as well as herself; (2) discover a way to notify Susan; and (3) discover how to obtain those notes. You may solve the three sub-problems separately. For example, you may realize that Rodney Wong in your 10:00 class passes by your industrial psych classroom and can see Susan – you have solved the second subproblem. Then it occurs to you that you can ask a librarian for a piece of carbon paper and some sheets of paper and ask Rodney to bring them to Susan; she can make a carbon copy as she takes notes for herself. The third subproblem is the easiest; Susan can bring the copy of the notes to the cafeteria, where you always eat lunch together.

When you use means-ends analysis to solve a problem, you can proceed in either the forward direction, from the initial state to the goal state, or backward from the goal state to the initial state. Thus, you may solve the third subproblem prior to the first subproblem. Try noticing the kinds of problem you might solve using means-ends analysis, perhaps writing a term paper for a history course, solving a problem in a statistics class, or figuring out the solution to numerous everyday dilemmas. Let us now examine some of the research showing how people use means-ends analysis in solving problems, as well as computer simulation investigations of this heuristic.

Research on the Means-Ends Heuristic. Research demonstrates that people do organize problems in terms of subproblems. Greeno used the Hobbits-and-Orcs problem in Demonstration 10.6. His study showed that people pause at points in the problem and plan their strategy for the next few moves. They do not move ahead at a steady pace through a long series of individual moves. Specifically, people took a long time before the first move and before two other critical moves. At each of these points, they were tackling a subproblem and needed to organize a group of moves.
In some cases, means-ends analysis might not be the best approach. Sometimes the solution to a problem depends on temporarily increasing the difference between the original state and the goal state. For example, how did you solve the Hobbits-and-Orcs problem? Maybe you concentrated on reducing the difference between the original state (all creature on the right side) and the goal state (all creatures on the left side) and you therefore only moved them from right to left. If you

did, you would have ignored some steps that were crucial for the solution of the problem: moving creatures backward across the river to the right side of the river.

A study by Thomas emphasizes people's reluctance to move away from the goal state – even if the answer ultimately depends on this temporary detour. One group of participants in this study worked through the Hobbits-and-Orcs problems in the normal order; they served as the control group. In contrast, a part-whole group began by solving the last part of the problem, starting at one of the points that required moving away from the goal. Then the part-whole group solved the entire problem, from beginning to end.

As you can see, people in the part-whole group gained an initial advantage from their experience on the last part of the problem:

They performed significantly better than the control group on the first part of the task. However, the difference between the two groups was not statistically significant for the second part of the problem: Both groups performed relatively poorly because they were reluctant to make the necessary detour. Notice, in contrast, that the part-whole group actually performed worse the second time around on the last part of the problem. When they tried it the first time, the detour was less apparent than it was the second time, with the background of progress through the first part of the problem.
In real life, as in Hobbits-and-Orcs problems, we sometimes find that the best way to move forward is to move backward temporarily. Think of an occasion when you were working on one of the later subproblems in a problem and discovered that a solution to an earlier subproblem was inadequate. For example, when you are writing a paper based on library research, you might discover that the resources you gathered during an earlier stage were not sufficient. Now you need to move backward to that earlier subproblem and revisit the library. You'll probably resent this task, especially because it seems to increase the difference between the original state and the goal state. In short, to solve a problem with means-ends analysis, we must sometimes violate a strict difference-reduction strategy.

Computer Simulation. Newell and Simon have examined means-ends analysis with a computer simulation approach. As discussed earlier in the book, in computer simulation a researcher writes a computer program that will perform a task the same way that a human would. For example, a researcher might try to write a computer program for the Hobbits-and-Orcs problem. The program should be no better at solving the problem than a human would be, and it also should be no worse. The researcher tests the program by having it solve a problem and noting whether the steps it takes match the steps that humans would take in solving the problem. In studying problem solving, computer simulation offers the same advantage mentioned in connection with computer simulation of language processes: It forces the theorist to be clear and unambiguous about the components of the theory.

Sometimes the computer program's performance does not match the performance of human problem solvers. This failure indicates to the researchers that their theory needs to be revised. If the researchers have created a program that does mimic human behavior, however, this success does not automatically imply that humans actually solve problems in this fashion. It is possible, for example, that another task could be devised for which the computer program and the human problem solver would perform differently. In psychology, we cannot "prove" that a theory is correct; we can only demonstrate that it is compatible or consistent with behavior. Thus, if a program does predict how humans will solve a problem, a theory can be tentatively accepted. If it does not predict problem solutions, a theory can be rejected.

What is the advantage of computer simulation? Why is it preferable to a theory stated in standard English? Many cognitive psychologists favor computer simulation because it allows them to express their theories in precise computer language. In contrast, standard English is much less explicit.
Newell and Simon developed a computer program called **General Problem Solver or GPS**, which is a program whose basic strategy is means-ends analysis. The goal of the GPS is not simply to solve problems in the most efficient way, but to mimic the processes that normal humans use when they tackle these problems. GPS has three different methods:

1. The transform method, which involves matching the original state to the goal state and finding the difference between them and then reducing the difference by producing a new and different state. As a final step, this new state is transformed into the goal state.

2. The apply-operator method, which involves determining whether the operator (an action that changes the problem from one state to another) can be applied to the original state. If so, apply the operator; if not, change it to a new state before applying the operator.

3. The reduce method, which involves searching for an operator that would help reduce the difference and then applying it to the original state to produce a new state.

Notice that these three methods are different ways of changing the original state into the goal state. The transform method involves creating a new, transition state; the apply-operator method involves finding a state to which the operator can be applied; and the reduce method involves a search for the right operator for the situation.

The General Problem Solver program developed by Newell and Simon was the first to simulate a variety of human symbolic behavior. GPS therefore has had an important impact on the history of cognitive psychology. It was used to solve transport problems like that of the Hobbits and Orcs, and it was successful in simulating human performance on this kind of problem.

In addition, the GPS was used in studying a number of general problems, such as the grammatical analysis of sentences, proofs in logic, and trigonometry problems. The GPS was eventually discarded by Newell and Simon because its generality was not as great as they had wished. However, GPS is important because it helped us understand better how humans solve problems using means-ends analysis.

In Depth: **The Analogy Approach**

Every day you use analogies to solve problems. To solve a problem on a mathematics problem set, you refer to previous problems in your textbook. To pronounce an unfamiliar English word, you think about other words with similar spellings. Analogies also figures prominently in creative breakthroughs in art and science. For example, some of Einstein's theories developed out of analogies.
In an **analogy**, we use a solution to an earlier problem to help with a new one. Analogies pervade human thinking. Whenever we try to solve a new problem by referring to a known, familiar problem, we are using an analogy. Educators are clearly aware of the power of analogies. In a survey conducted by Halpern, virtually every college-level course in critical thinking or creative thinking emphasized course instruction on using analogies.

Researchers have enthusiastically examined how problem solvers use analogies. In fact, a book on analogical problem solving argues that analogies constitute a prototypical research topic in cognitive psychology. Let's now examine a portion of this research, beginning with an overview of some important background studies and then focusing on some recent research by Laura Novick.

Background Research. The challenge for people who use the analogy strategy is to determine the real problem, that is, the abstract puzzle underneath all the details. In the section on understanding problems, we emphasized that the problem solver must peel away the unimportant layers in order to reach the core of the problem. For example, when you went through Hobbit problem, you realized that you did not need to know anything about Hobbits and Orcs-except for characteristics that were relevant for getting them across the stream. The story could just as well have concerned residents of different planets. These sets of problem with the same underlying structures and solutions – but with different specific details and contexts – are called **problem isomorphs**.
If people appreciate the concept of problem isomorphs, then they should be able to classify various kinds of algebra word problems. In one study, Hinsley, Hayes, and Simon wanted to see

whether people could classify various kinds of algebra word problems. They asked high-school and college students who had taken courses in algebra to sort problems selected from a high-school algebra text-book. They were given 76 problems and were simply told to sort the cards into piles by problem type. The phrase "problem type" was not defined, nor was the number of piles. People did categorize the word problems into clusters. Furthermore, they showed strong agreement about what the categories were.
In their research, Hinsley and his co-workers devised 18 different clusters of algebra problems. The following three examples are typical:

- *River current*. A river steamer goes 36 miles downstream in the same amount of time that it travels 14 miles upstream. In still water, the steamer would travel at a rate that is 12 miles an hour faster than the rate of the current. What is the rate of the current?
- *Work*. Mr. Jones takes 3 minutes less than Mr. Smith to assemble a machine when each work alone. One day, Mr. Jones spent 6 minutes assembling a machine and then left; Mr. Smith finished the machine in 4 more minutes. How long would it take Mr. Jones, working alone, to assemble a machine?
- *Number*. In a certain number, the digit in the units place is 1 more than 3 times the digit in the tens place. If you switch the numbers around, you get a number that is 8 times the sum of the digits. What is the number?

Hinsley and his co-workers found that people could categorize a problem very early during its presentation. As thy write,

For example, after hearing the three words, "A river steamer……" from a river current problem, one subject said, "It's going to be one of those river things with upstream, downstream, and still water. You are going to compare times upstream and downstream…."

People may be able to categorize problem types. However, researchers typically find that people often ignore these analogies when they actually need to solve a problem. For example, Reed found that people often showed little transfer between the Hobbits-and-Orcs problem and a similar but more difficult problem traditionally known as the "jealous-husbands problem." Holyoak and Koh have confirmed that people are often reluctant to see the analogy between a problem they have solved and a new problem isomorph.
Reed and his coauthors are also pessimistic about student's ability to use analogy information appropriately. In a series of experiments, these authors demonstrated that students in a college algebra course had difficulty transferring their knowledge between similar problems for distance, mixture, and work-rate word problems. In particular, they tended to make errors when substituting a new numerical value for the appropriate numerical value in the original problem. The authors suggest that students would make fewer errors if they were to construct tables listing the values of the important variables in both the original and the new problem.

This research shows that the analogy strategy should be useful. However, problems solvers too often fail to detect the analogy, and they may also make errors in interpreting it. **VanLehn** concludes in his summary of this research that people seldom notice a potential analogy, and when they do notice the analogy, it is likely to be based on superficial features, rather than true, structural similarities.

Novick's Research. Let's now consider research by Laura Novick, which explores why people have difficulty transferring their knowledge from one problem to a second, analogical problem. As she points out, experimenters and people who read about the research on analogical problem solving find this research puzzling. It seems so obvious that a person who has been given a problem to solve should search back to find other, similar problems solved just minutes earlier! The difficulty, according to Novick, is that problem solvers – especially novice problem solvers – focus on salient **surface features**, which are the specific objects and terms used in the question. For example, recall that the person in the research by Hinsley and his coauthors classified a problem as a river current problem after hearing only three words, "A river

steamer…." Unfortunately, these problem solvers may fail to emphasize the **structural features**, the underlying core that must be understood in order to solve the problem correctly.

Let's use some standard terminology for analogical problem solving. Imagine that you are currently trying to solve a problem; this current problem is called the **target problem**. To solve the target problem, you should look for a similar problem you solved in the past, called a **source problem**.

Novick wanted to see how the expertise of the problem solvers influenced the way they selected a source problem. In particular, she proposed that novice problem solvers would select a source problem that resembled the surface features of the target problem. In contrast, expert problem solvers would be more likely to select a source problem that resembled the structural features of the target problem.
Novick tested college undergraduates and categorized them into expertise categories on the basis of their scores on the mathematics section of the Scholastic Aptitude Test (SAT). She argued that the SAT is a valid way to categorize student's in her research because the problems on that test are similar to the problems she presented to the students.

Imagine that you are a participant in Novick's study. In the beginning, you are given three problems to solve, these serve as the source problems. Each problem is also accompanied by an explanation of the solution. After these three problems, Novick hands you the target problem, and you are instructed to solve it. This target problem resembles the surface features of the first source problem. However, it resembles the structural features of the second source problem, because it requires you to figure out the lowest common multiple (for example, 10 x 4 x 5). The only similarity that the target problem shares with the third source problem is that both require some arithmetic calculations.

Novick examined college student's calculations for the target problem in this study to determine whether their solution relied on the earlier problem that had been similar in surface or the one that had been similar in structural features. The experts were slightly more likely to emphasize structural similarity, whereas both categories of novices were much more likely to emphasize surface similarity.

Thus, Novick's research shows us that experts are often able to unpeel the layers of math problems and notice that at the core, two problems share structural similarities. To solve the target problem, the expert uses the strategies that were successful in solving that structurally similar source problem. In contrast, people with less expertise miss the appropriate analogy, relying instead on similarities that are unimportant.

In a later article, Laura Novick and Keith Holyoak pointed out that successful problem solving by analogy requires four different processes:

i. **Retrieval**, or locating the appropriate source problem;
ii. **Mapping**, or constructing orderly correspondence between the parts of the source problem and the parts of the target problem;
iii. **Adaptation**, or determining how to use the same procedures for the target problem that were successful for the source problem; and
iv. **Learning**, or figuring out an abstract schema for the entire class of problems that the source problem and the target represent.

The research on using analogies to solve problems suggests that analogies are extremely useful – when they are used appropriately. Unfortunately, however, the appropriate use of analogies requires four intellectually challenging hurdles. As a consequence, novice problem solvers may not be successful in exploiting these analogies.

Factors That Influence Problem Solving

How will you approach the next problem you face, and how successfully will you solve it? We cannot answer that question unless we know some information about you – the problem solver – and about the problem you are about to attack. For example, we would want to know about your level of expertise and whether you have a certain mental set. Relevant characteristics of the problem include the functional fixedness of any objects to be used in solving the problem, whether the problem is well-defined or ill-defined, and whether the problem requires insight.

Expertise

As we saw in Novick's research, experts and novices differ in the way they use the analogy approach. How else do experts differ from novices in the way they solve problems? Experts aren't simply "smarter" than other people. For instance, Ceci and Liker found that people who were experts at betting for horse races did not have higher IQ's than nonexperts. Furthermore, experts excel primarily in their own domains of expertise. You wouldn't expect a racetrack expert to excel at the problem of creating a Northern Italian meal from unfamiliar ingredients!

Let's trace how experts differ from novices during many phases of problem solving. We'll begin with some of the basic, early steps, then remind you about how experts differ from novices in intermediate phases, such as appreciating structural similarities, and finally consider more general issues, such as *metacognition*.

Memory. Experts differ from novices with respect to their memory for information related to their area. For example, expert chess players have much better memory than novices for various chess positions. De Groot briefly showed chess positions to novices and experts and then requested recall. The expert were far superior in recall the positions, even though they were no better at remembering random arrangements of the chess pieces. In other words, their memory is better only if the chess arrangement fits into a particular schema. Similarly, people who are experts at the game Othello are also superior at recalling meaningful game patterns, but not random positions. Because memory for relevant information is an important part of problem solving, the experts have a clear advantage over the novices in game performance.

Knowledge Base. Novices and expert also differ substantially in their knowledge base, or schemas found in their study of physics problem solving that the novices simply lacked important knowledge about the principles of physics. As we discussed, you need the appropriate schemas in order to understand a topic properly.

Representation. Furthermore, novices and experts represent the problem differently. Larkin found that the novices in her study were likely to use naïve problem representations, involving objects in the real word such as blocks, pulleys, and toboggans. The experts were able to construct physical representations about abstract ideas such as force and momentum. Other researchers have found similar results. Experts are also more likely to use appropriate mental images or diagrams, which are likely to facilitate problem solving.

Appreciating Structural Similarity. As we emphasized in the In-Depth section, experts are more likely than novices to appreciate in structural similarity between mathematics problems; they are less likely to be distracted by surface similarities. The same findings have been reported for experts and novices solving physics problems.

Elaborating on Initial States. Experts are more thorough than novices in thinking about the initial states of a problem. For example, Voss and his coauthors studied three groups of people with differing levels of expertise about the Soviet Union. The experts on this task were political scientists whose area was Soviet affairs. The two novices groups included one group of chemistry professors and one group of students. These researchers examined the protocols, or spoken records collected during problem solving. The Soviet experts frequently began by identifying possible constraints in the problem, such as the amount of usable land and Soviet ideology. In all, 24 percent of the protocols of the Soviet experts elaborated on the initial state of the problem, in contrast to only 1 percent of the protocols of each novices group.

Speed and Efficiency: As you might expects, experts are much faster than novices, and they solve problems with little error. Their operations become more automatic, and a particular stimulus situations also quickly triggers a response. Experts also seem to have a more coherent, efficient plan for problem solving.
On some tasks, experts may solve problems faster because they use parallel processing, rather than serial processing. As the discussion on attention noted, parallel processing handles two or more items at the same time. In contrast, serial processing handles only one item at a time. Novick and Core examined experts who reported that they could solve anagrams quickly, and novices, who said their anagram-solving skills were "awful". The experts solved this anagrams so quickly that they must have been considering several alternate solutions at the same time. To experts, the solution to anagram such as DNSUO, RCWDO, and IASYD seemed to "pop out" in less than 2 second. In contrast, the novices were probably using serial processing. (Incidentally, are you a novice or an expert anagram solver?)

Metacognitive Skills. Experts are better at monitoring their problem solving; you may recall that self-monitoring is a component of metacognition. Experts seem to be better at judging the difficulty of a problem. They are also more aware when they are making an error, and they are more skilled at allocating their time appropriately when solving problems. In short, experts are more skilled at numerous phases of problem solving and are even more skilled at knowing how well they are doing in solving the problem at hand.

Mental Set

When problem solvers have a mental set, they keep trying the same solution they have used in previous problems, even though the problem could be approached via other, easier ways. Mental sets involve a kind of mindless rigidity that blocks effective problem solving. Although problem solving demands both top-down and bottom-up processing, overactive top-down processing produces a counterproductive mental set. The classic experiment on mental set is the Luchins water – jar problem.[fig]

The best way to solve Problem 1 is to fill up jar B and remove one jarful with jar A and two jarsful with jar C. Because Problems 1-5 can all be solved in this fashion, they create a set for the problem solver. Most people will keep using this method when they reach Problems 6 and 7. however, this past learning will actually be a disadvantage, because there are easier, more direct ways of solving these later problems. Problem 6 can be solved by substracting C from A, and Problem 7 can be solved by adding C to A. Luchins found that almost all of the participants to whom he gave such complex problem as 1-5 persisted in the same complex kind of solution on later problems. On the other hand, control-group participants, who began right away with problem such as 6 and 7, almost always solved the problem in the easier fashion.

A mental set often works against us in our everyday experiences, too. Consider, for example, the problem of getting to a particular inn a nearby city. Perhaps you derived a long, elaborate route involving many turns –a route that you have used for years – only to find out that someone else had discovered a simpler, more direct route on the first try.

So far, we have considered two characteristics of the problem solver – expertise and mental set – that influence how a problem is solved. Now we will examine three characteristics of a problem – other than the nature of the problem itself-that influence problem solving: *functional fixedness, whether the problem is well defined or ill defined, and whether or not the problem requires insight*. We need to emphasize as well that some problems are simply more difficult than others. For example, Kotovsky and his coauthors examined a problem called the Tower of Hanoi, which resembles the monster-and-globe problem you perhaps have tried They found that different problem isomorphs varied greatly in their difficulty, with one isomorph requiring 16 times as long to solve as other versions; memory load was a strong determinant difficulty. Let us now turn to three other important determinants of problem solving.

Functional Fixedness

Functional fixedness means that the functions or uses we assign to objects tend to remain fixed or stable. To overcome functional fixedness, we need to think flexibly about other ways that objects can be used. My sister, for example, described a creative solution to a problem she faced on a business trip. She had purchased a take-out dinner from a wonderful Indian Restaurant. Back in her hotel, she discovered that the bag contained no plastic spoons or forks, and the hotel dining room had closed several hours earlier. When to do? She searched the hotel room, discovered an attractive new shoehorn in the "complimentary packet," washed it thoroughly, and enjoyed her chicken biriyani. To overcome functional fixedness, she had to realize that an object designed for one particular function (putting on shoes) can also serve another function (conveying food to the mouth).
The history of technology offers numerous examples of overcoming functional fixedness. For instance, the steam engine was used for a century to pump water out of mines before an inventor realized that it could be used as a source of locomotive power.
Notice, incidentally, that functional fixedness describes a characteristics of objects in a problem-solving task, whereas mental set describes a characteristic of problem solvers. However, both characteristics block effective problem solving. Also, research has demonstrated that the two concepts are related. For example, McKelvie administered the Luchins water-jar problem to college students, and then four weeks later he administered a functional fixedness task to the same students. The people who were most susceptible to mental set also had the most difficulty in overcoming functional fixedness.

The classis study in functional fixedness is called Duncker's candle problem. Imagine that you have been led to a room that contains a table. On the table are three objects, a candle, a box of matches, and a box of thumbtacks. Your task is to find a way to attach the candle to the wall of the room so that it burns properly, using no other objects than those on the table. Most people approach this problem by trying to tack the candle to the wall or by using melted wax to try to glue it up; both tactics fail miserably! The solution involves overcoming functional fixedness by tacking the empty matchbox to the wall to serve as a candle holder.

Functional fixedness and mental sets are two more examples that states that mistakes in cognitive processing can often be traced to a strategy that is basically very rational. In general, objects in our world have fixed functions. For example, we use a hammer to pound in a nail and a wrench to tighten a bolt. The strategy of using one tool for one task and another tool for another task is generally very wise; after all, each was specifically designed for its own task. Functional fixedness occurs, however, when we apply that strategy too rigidly and fail to realize, for instance, that if all other tools are missing, a wrench could be used to pound in the nail. Similarly, it is generally a wise strategy to use the knowledge you learned in solving earlier problems to solve the present problem. If an old idea works well, keep using it! However, in the case of mental sets, we apply the strategy gained from past experience too rigidly and fail to notice more efficient solutions.

Well-Defined and Ill-Defined Problems

Most of the problems we have considered so far could be called well defined. A **well-defined problem** is one in which the original state, the goal state, and the rules are all clearly specified. In addition, we have some systematic way to help us decide whether a solution is correct. In an anagram, for example, we know when we have reached a correct decision.

However, most of our daily problems are ill defined. An **ill-defined problem** is one in which the original state, the goal state, or the rules are unclear. Furthermore, we have no systematic way of telling whether a solution to an ill-defined problem is correct. Some representative ill-defined problems include saving money for college tuition, de-escalating the nuclear arms race, and improving the environment.

Simon describes another ill-defined problem: an architect designing a house. Notice, incidentally, that an architect could take a well-defined approach to the problem by selecting a

standard house design and duplicating it. If she intends to create an original design, however, the problem is certainly ill defined. She could consider all kinds of structures, such as geodesic dome, an A-frame, arches, and so on. She would also have to consider many varieties of material, such as wood, metal, concrete, camel's hides, marble, granite, rubber, ice (as Simon notes, don't object to ice-it's been done). Furthermore, there would be many different ways of proceeding. She might start with floor plans, or with the design for the front of the building, or with a list of needs stipulated by the client. Very few aspects of this problem are clearly defined. Furthermore, the architect would have no way of knowing whether or not she has reached a correct solution, though she certainly would know whether she had solved an anagram correctly.

We discussed algorithms and heuristics that could be used to solve well-defined problems. One of these heuristics can also be used for ill-defined problems; you can divide a problem into several subproblems. Another strategy is to add more structure to the situation. One difficulty with an ill-defined problem is that the task has few constraints or limitations. To reach a solution, we must somehow restrict the possibilities. For example, when faced with the ill-defined problem of writing a paper for your course in cognitive psychology, you might restrict the possibilities by considering only those topics that relate to education.
Other strategies for solving ill-defined problems include starting to work on the problem even if you do not yet understand it completely and stopping when you have a solution, although it may not be the best possible solution. Because an ill-defined problem has no single, ideal solution, we can adopt a different criterion for success than with a well-defined problem.

Insight and Non-Insight Problems

When we experience **insight**, the solution to a problem suddenly enters our minds and we immediately realize that the solution is correct.

The concept of insight was very important to Gestalt psychologists. Gestalt psychologists emphasized the importance of organizational tendencies. They argued that the parts of a problem may initially seem unrelated to one another, but a sudden flash of insight could make the parts fit together into a solution.
Behaviorist psychologists rejected the concept of insight because insight's emphasis on a sudden cognitive reorganization was not compatible with their emphasis on observable behavior. However, with the rise of the cognitive approach, psychologists once again use the term freely.
Janet Metcalfe argues that people working on insight problems experience a sudden leap in their confidence about being close to a correct solution. In contrast, our confidence builds gradually for problems that do not require insight, such as standard high-school algebra problems. In fact, Metcalfe and Wiebe argue that the sudden rise in confidence can be used to distinguish insight from non-insight problems.

Let us examine Metcalfe's paper on solution patterns for insight problems. Metcalfe posed the following problem to students:

A stranger approached a museum curator and offered him an ancient bronze coin. The coin had an authentic appearance and was marked with the date 544 B.C. The curator had happily made acquisitions from suspicious sources before, but this time he promptly called the police and had the stranger arrested.

As students worked on this problem, they supplied ratings every 10 seconds on a "feeling – of – warmth" scale. A rating of 0 indicated that they were completely "cold" about the problem, with no glimmer of a solution. A score of 10 meant that they were certain they had a solution.

If you figured out the answer to the coin question, did you experience this same sudden burst of certainty? (Incidentally, the answer to this problem is that someone who had actually lived in 544 B.C. could not possibly have used the designation B.C. to indicate the birth of Christ half a millennium later).

Creativity

Perhaps you breathed a sign of relief as you finished the sections on problem solving and prepared to read a section on creativity. Problem solving sounds so routine, whereas creativity sounds inspired. People who solve problems sit around working out their means-ends analyses, whereas people who think creatively have light bulbs flashing above their heads.
Truthfully, however, creativity is an area of problem solving. Creativity, like the areas of problem solving we have already considered, requires moving from an original state to a goal state. However, creativity is more controversial because we have no single standardized definitions of creativity and no single widely accepted way to measure it. We will discuss definitions and measurement techniques and then examine several factors that may influence creativity.

Definitions

An entire chapter could be written on the variety of definitions for creativity. However, most theorists agree that *novelty* is a necessary component of creativity. However, novelty is not enough. The answer we seek must also allow us to reach our goal; it must be practical and useful. Suppose I asked you to construct a creative answer to the question, "How can you roast a chicken?" The nineteenth-century essayist Charles lamb observed that one way to roast a chicken would be to put it into a house and then burn the house down. This answer meets the criterion of novelty, though it does not fulfill the usefulness requirement. To most theorists, then, creativity involves finding a solution that is both unusual and useful.

You will notice that the definition of creativity did not specify intelligence. Certainly the two concepts are related, though they are not identical. At a broad sample of people, intelligence is somewhat correlated with creativity. As Hayes suggests, one explanation for this general correlation is that a person must be at least moderately intelligent to attain an occupation that encourages creative projects. However, if you examine professionals in a given occupation (who therefore met the minimum criterion for intelligence), the more creative people and the less creative people are likely to have similar IQs. *Intelligence is necessary – but not sufficient – to produce creativity.*

Measuring Creativity

If theorists disagree about the definition of creativity, how can they possibly agree about how to measure it? As you might imagine, they do not agree at all. Furthermore, no current test of creativity consistently predicts which people will be more creative in real-life situations. Numerous tests are available, however; Mansfield and Busse discuss 20 different measures, for example.
Let us consider three different approaches to creativity: Guilford's Divergent Production Tests, Mednick and Mednick's Remote Associates Test, and Amabile's more recent consensual assessment technique.

Divergent Production. Guilford's test emerges from his idea that people have at least 120 different, independent kinds of mental abilities. Some of these abilities involve memory, some involve evaluating or judging, and some (in fact, 24) involve divergent production. In **divergent production**, people make a number of varied responses to each test item. Demonstration 10.10 shoes some of the 24 ways in which Guilford measured divergent production.
Guilford discusses some of the support for Divergent Production Tests. In one study, for example, public relations and advertising employees were judged by their superiors to be either "creative" or "less creative". All employees then took the Divergent Production Tests. On five of the eight tests, the creative employees did significantly better than less creative employees. On the other hand, Guilford comments, "Correlations between DP (Divergent Production) test scores and criteria of creativity during the years through high school have not been spectacular, to say the least". Others criticize the concept of divergent production, noting that number of unusual

ideas bears little relationship to creativity and that different measures of divergent production are not as highly correlated with each other as they should be.

Remote Associates Test. The Remote Associates was devised by Mednick and Mednick to measure their concept of creativity. These authors interpreted creativity to mean the ability to see relationships among ideas that are remote from one another. Creative people can take far-flunk ideas and combine them into new associations that meet certain criteria.
the **Remote Associates Test** is a test of creativity; the items consist of three words that must be linked together with a single word.

Mednick and Mednick cite several studies demonstrating a relationship between RAT scores and creative performance. For example, scientists in a chemical firm who have high RAT scores also have high job classification. Also, psychology graduate students who have high RAT scores tend to be rated as highly creative by their research advisors. Furthermore, technicians with IBM who have high RAT scores are more likely to make award-winning suggestions for improvement of the company.

A study by Andrews points out that creativity, as assessed by tests such as the RAT, may be related to real-life creativity only if all the circumstances are ideal. He located 115 scientists who had directed research projects. The scientists took the RAT, and they also answered questions about the laboratory environment in which they worked. Independent judgments were obtained on the quality of their scientific output. Andrews found no relationship between RAT measures and scientific output. However, he conducted another analysis and found that there was a relationship if the environmental factors were examined as well. Some of the scientists worked in a situation in which they had opportunities for innovation, made decisions about the research, felt professionally secure, and worked independently. For these scientists, high RAT scorers had greater scientific output than low RAT scorers. For the people who worked in less pleasant situations, there was no significant correlation. Andrews' results therefore suggest that in ideal work settings, scores on the RAT may be related to real-life measures of creativity.

However, not all the research offers optimism for the RAT. Reviews of the research on the RAT conclude that people who score high on the RAT sometimes show superior creative achievement, but sometimes they do not. Unfortunately, the reasons for the inconsistent results are not clear.

Consensual Assessment Technique. Teresa Amabile has developed a third alternative to the measurement of creativity. She points out that we can look at creativity as a property of products, rather than of people. According to the **consensual assessment technique**, a product should be considered creative if observers who are familiar with the area agree that it is indeed creative. Her research indicates that observers who are familiar with an area tend to agree with one another in their creativity assessments. For example, trained artists rated young girls' artwork in one study, and they agreed with one another about assessments of which artwork was creative and which was not. Their ratings also tended to agree with the ratings of art teachers and the ratings of novices.

Amabile's technique has some clear advantages. For example, it's hard to argue with the logic of a definition of creativity that can be paraphrased, "If experts think this work is creative, then it is." In addition, the straightforward measurement technique makes it easier to conduct research on the factors that influence creativity. We will look at some of this research in the final section.

Fostering Creativity

Psychologists may disagree about how to define and measure creativity. However, they would agree in supporting efforts to enhance creativity. Let's consider two popular techniques designed to enhance creativity and then consider two additional factors that can affect creativity.

Brainstorming. One of the most common approaches to encouraging creativity is Osborn's brainstorming principle. **Brainstorming** is a process conducted in a group setting in which these are four basic guidelines:

1. Evaluation of ideas must be withheld until later; thus criticism is ruled out.
2. The wilder the idea, the better. It is easier to tame an idea later than to think one up.
3. The greater the number of ideas, the better.
4. People can combine two or more ideas proposed by others.

Osborn maintains that the spirit of a brainstorming session is important. People should encourage themselves as well as encourage one another. Complete friend-liness and a relaxed frame of mind are especially important.
The brainstorming technique has had good publicity in the popular press. Recently, however, psychologists have become increasingly skeptical about the value of this technique. Weisberg's review of the literature, for example, questions both the assumptions underlying brain-storming and its practical usefulness. Weisberg does not agree with the assumption that creativity depends on the number of diverse ideas produced. Perhaps more important, research suggests that people can often be more creative working alone than working in groups. Furthermore, brainstorming groups may produce a greater number of ideas than groups urged to think critically, but their ideas are often lower in quality. Brainstorming may indeed be effective in some circumstances, but it does not seem to guarantee creative production of ideas.

Synetics. Another approach to encouraging creativity is called synectics. **Synectics** encourages the use of analogies in creative thinking. The method includes the following of analogies:

1. The personal analogy encourages you to place yourself directly in the situation. For example, if you want to make a particular machine work more efficiently, imagine that you are that machine.
2. The direct analogy encourages you to find something else that solves the problem you are examining. Very often it is helpful to look at solutions provided by human or animal biology. Alexander Graham Bell did this when he considered how the relatively huge bones of the human ear could be moved by a relatively delicate membrane, and he invented the telephone, in which a piece of steel is moved by a membrane. More recently, biologist Michael Zasloff was searching for a new approach to the study of infectious diseases. He pondered why frogs, which live in scummy, bacteria – filled ponds, naturally occurring substances in frog skin that can kill a range of microbes.
3. The symbolic analogy uses objective, impersonal, or poetic images to describe a problem. Gordon describes a synectics group that designed a new, smaller automobile jack by first thinking of the Indian rope trick (the one you may have seen in cartoons, in which a turbaned Indian makes a soft rope rigid enough to climb on).

Gordon describes how the synectics method has been used in industry, business, and education. For example, participants in a synectics session on the problem of science and public policy tried imaging themselves as nocturnal animals and as little fish being swallowed by big fish on the Florida Keys. The answer finally emerged when they formed an analogy between the government and the garment industry. They concluded that the government – like successful garment designers – should seek nontraditional solutions to problems.
Does the synectics method work? As Gilhooly points out, the method has been widely used by industries and other organizations. However, we do not yet have substantial research to document whether it truly enhances creativity.

Incubation and Creativity. Have you ever worked on a creative project and come to an impasse – then found that the solution lept into your mind after taking a break? Many artists, scientists, and other creative people testify that incubation helps them solve problems creatively. **Incubation** means that you are more likely to solve a difficult problem if a delay is placed between a period of intense work on the problem and a second work session.
Incubation sounds plausible. However, incubation is seldom demonstrated in well-controlled research, even though the anecdotal evidence is abundant. Perhaps more ecologically valid

research should be conducted with creative individuals solving real-life artistic, scientific, and conceptual problems.
Assuming that incubation occasionally does work, what would be some likely mechanisms? Some theorists propose that unconscious processes are at work during that incubation period. Another possibility is that inappropriate mental sets may decay during that delay period. Furthermore, this incubation period may allow time for the spread of activation between related concepts, especially for tasks that require verbal creativity.

Social Factors Influencing Creativity. You may have noticed that our discussion of factors influencing creativity has been rather tentative so far. We have described two methods that are supposed to enhance creativity, yet research support for their efficacy is slim. We also lack strong evidence for the value of incubation. Fortunately, the research on social factors is much more impressive.
For example, we know that creativity is reduced when people know that others will be evaluating their work. In a representative experiment, college students were told to compose a poem. Half were told that the experimenter was simply interested in their handwriting, not the content of the poem, and therefore they did not expect to be evaluated on their poems. The other half were told that the experimenter was interested in the poem's content, and they would receive a copy of the judges' evaluations of their poems. Therefore these people expected to be evaluated. Half of the people in each of these groups worked alone, and half worked with others who were also composing poems.
Each of the poems was judged according to the consensual assessment technique, using judges who were poets. As you can see, people produced poems that were much less creative when they expected to be evaluated. Creativity was inhibited by evaluation expectation, whether people worked in isolation or with others. However, people were equally creative in the "working together" and "working alone" conditions.

Amabile presents other convincing evidence that evaluation expectation can undermine creativity. For instance, the effect holds true for both adults and children, and for both artistic creativity and verbal creativity. When you expect you work to be evaluated, the product may not be less appealing or less technically appropriate, but it is likely to be less creative.
Research has also documented how other social factors can influence creativity. Amabile outlines how creativity is reduced under these conditions:

When someone is watching you while you are working;
When you are offered a reward for being creative;
When you must compete for prizes; and
When someone restricts your choices about how you can express your creativity.

Undergraduate students in psychology often think that all the interesting research questions may have been answered. In the area of creativity, we certainly have not answered all the questions. Furthermore, if we take seriously the challenge of problem finding that was raised at the beginning of the chapter, we probably have not yet identified many of the interesting questions.